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Water Budget for the City of Laramie, Wyoming

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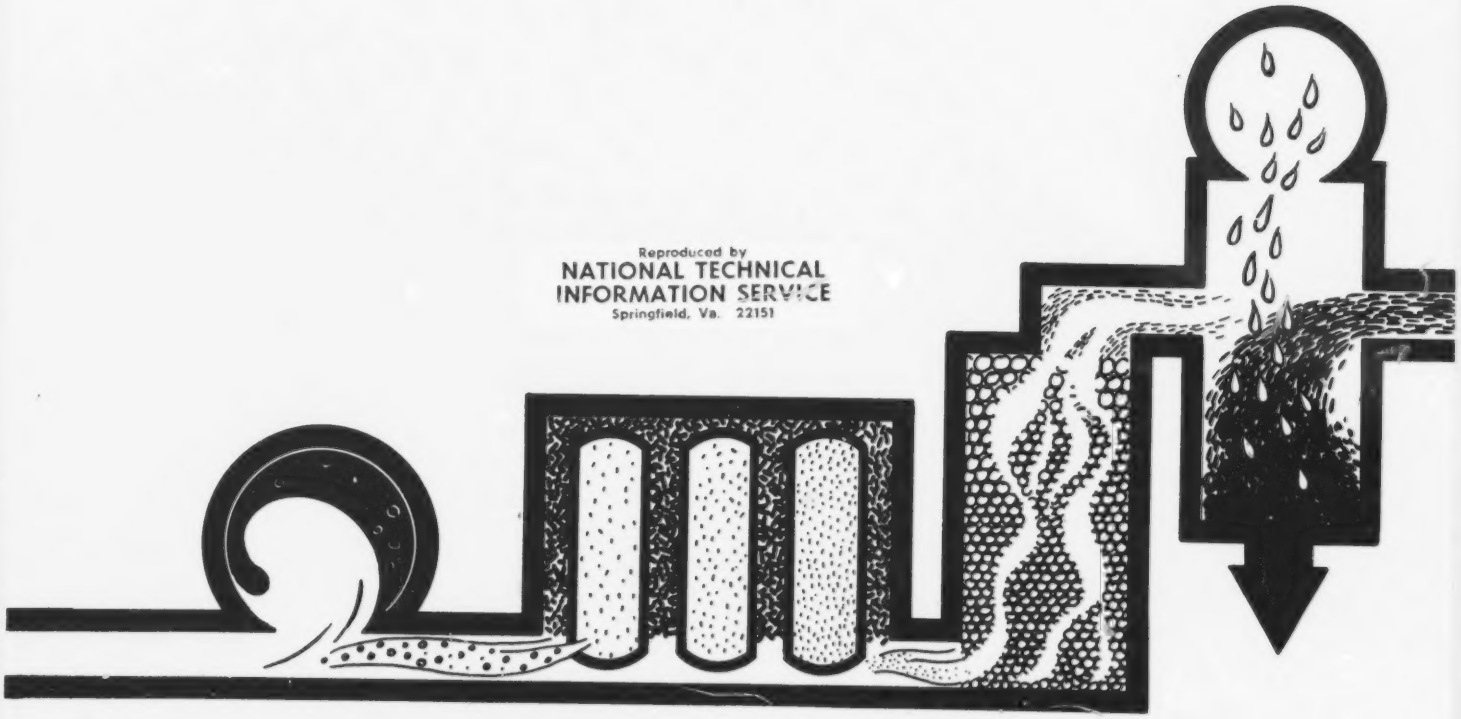

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WATER BUDGET FOR THE CITY OF LARAMIE, WYOMING,

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Rechard, Paul A.

Wyoming University, Laramie, ~~Wyoming,~~
Water Resources Research Institute.

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The water budget for the city of Laramie, Wyoming, was calculated for the years 1966-1970 in order to supplement studies of the city's sewage lagoons and to estimate the effects of municipal use on the Laramie River. The municipal usage averaged 184 gpcd for an average population of 22,500 during the 5 year period. Usage during the summer months (April-September) varied directly with temperature and inversely with rainfall, with an average of 235 gpcd. Average summer return flows were 105 gpcd. For winter conditions (October-March) average usage was 134 gpcd, with 140 gpcd returning to the river. The river furnished approximately 1/3 of the annual supply, and more than 1/2 of the summer supply. On an annual basis, however, the city returned more water to the river than it withdrew. (Lowry-Texas)

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WATER BUDGET FOR THE CITY OF LARAMIE, WYOMING

by

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for the

ENVIRONMENTAL PROTECTION AGENCY

Project #17050 DVO

September 1971

EPA Review Notice

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ABSTRACT

The water budget for the City of Laramie, Wyoming was observed for a five-year period (1966-1970). The purposes were to supplement studies of the operation of the city's sewage lagoons and to define the effects of municipal use on the Laramie River which furnished part of the water supply and was the receiving stream for the sewage effluent.

It was found that the river furnished approximately one-third of the annual supply and more than one-half the supply during the summer irrigating season. The city returned to the river about fifty percent of the water received during the summer (April-September) and eighty-five percent during the winter (October-March).

The municipal supply averaged 184 gallons per capita per day during the period of the study and varied from 134 gpcd during the winter to 235 gpcd during the summer. The average return flow to the river was 115 gpcd with 140 gpcd returning in the winter and 105 gpcd in the summer period.

This report was submitted in fulfillment of Project Number 17050DVO under the partial sponsorship of the Environmental Protection Agency.

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SECTION I

CONCLUSIONS

Assuming the population of the City of Laramie, Wyoming during the period of study averaged 22,500, the mean municipal requirement was 184 gallons per capita per day (gpcd). The winter period (October-March) demand was 134 and the summer period (April-September) demand was 235 gpcd. These figures compare favorably with those suggested by Langbein in 1949 (Langbein, 1949:997-1001); are somewhat higher than those found by Linaweaver, Geyer and Wolff in 1967 (Linaweaver, Geyer and Wolff, 1967); and almost duplicate the estimates of use in Laramie found by City Engineer E. K. Nelson in 1940 (Nelson, 1940). The average annual per capita use at Laramie appears to be similar with that experienced at Boulder and Denver, Colorado, although the variations between summer and winter are greater in the Colorado cities than at Laramie (Flack and Martinez, 1966).

The return flows approximate 115 gpcd on an average annual basis with little monthly variation (140 gpcd in June to 105 gpcd in November).

SECTION II

RECOMMENDATIONS

This study was undertaken as a cooperative effort with Dr. Robert L. Champlin who investigated the problems of aeration of sewage lagoons in the rigorous climate of Laramie, Wyoming. The water budget of the City was felt to be important to the overall program.

It is recommended that the municipal use water budget not be studied further. Apparently, the per capita use in Laramie is quite stable and further study would be sterile, except as a teaching tool.

Laramie is fortunate in that the storm sewer system is separate from the sanitary sewer system. It is recommended that the quantity, timing, and quality of storm runoff from Laramie be given further study.

Much of the municipal and industrial effluent in Wyoming will be evaporated, rather than allowed to return to the streams of the state. It is recommended that further study of high elevation evaporation be undertaken in order that data might be available for the design of evaporation ponds.

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SECTION III

INTRODUCTION

The population of cities and urban areas is increasing throughout the West. Municipalities are faced with the need to obtain additional water supplies to accommodate the continued influx of people. One method for supplying the required water is for the municipality to purchase an agricultural water right and transfer that right to municipal use. The possibilities and problems of accomplishing a transfer of a water right have been mentioned recently in the literature. Trelease and Lee, discussing the legal aspects of this means of furnishing the additional supplies, set forth the problem as follows:

> "Today the major prospect of growth of the West does not lie in the expansion of agriculture. Indeed, irrigation may have to contract. The population is moving to the cities. Technology and industry are the mushrooming sources of wealth. These cities and industries will need water. They cannot take their place at the bottom of the priority list by making new appropriations of the meager and uncertain supply of unappropriated water. They must get firm rights, and the oldest and best rights are held by agriculture." (Trelease and Lee, 1966:2)

Fox, in a discussion of the political or popular concern for making water available to people in water-short areas, stated:

> "In the absence of new sources of low cost water, ways must be found for supporting more people with a given quantity of fresh water if the growth of the West we anticipate is to be accommodated. . . . (T)he pattern of water use in the West must change. . . . (T)he task of the policy maker is to provide an environment which will facilitate an orderly transition in water use where such a transition is desirable." (Fox, 1960)

Continued development of Wyoming and much of the West will be more and more dependent upon the transfer of water rights from agricultural to municipal and/or industrial uses. While the accomplishment of some water right transfers are faced with legal entanglements and administrative reluctance, the water laws of most of the Western states (those embracing the prior appropriation doctrine) provide for transfer of rights from irrigation purposes to a use which is higher on a designated preference list. In Wyoming, the locale for this study, the preferred order is:

> "First -- water for drinking purposes for both man and beast; Second -- water for municipal purposes; Third -- water for the use of steam engines and for general railway use, water for culinary, laundry, bathing, refrigeration

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(including the manufacture of ice), for steam and hot water heating plants, and steam power plants; and Fourth -- industrial purposes. The use of water for irrigation shall be superior and preferred to any use where water turbines or impulse water wheels are installed for power purposes; . . ." (Bishop, 1969)

Thus, it would seem that, in Wyoming, water rights acquired for irrigation purposes may be transferred to municipal uses. However, a transfer in the place of use must be accomplished without jeopardizing the water rights of other appropriators. The Wyoming Supreme Court in the 1904 case of Johnston v. Little Horse Creek Irrigating Co., stated:

"The only limitation upon the right of sale of a water right separate from the land to which it was first applied, and to which it has become appurtenant, laid down by any of the authorities, is that it shall not injuriously affect the rights of other appropriators." (Emphasis added.) (Johnston v. Little Horse Creek Irrigating Co. 1904)

While this case did not deal with a transfer of use from agricultural to municipal, the caveat has been applied by administrators and the courts alike for all types of transfers.

In general, development in the West has been along streams and rivers where water was easy to divert from its natural channel for the irrigation of nearby lands. Water being so essential to the existence of life, communities also sought a stream bank location. As the settlements grew, the encroachment of urban development onto lands previously utilized for agricultural purposes and the subsequent transfer of the water from irrigation use to municipal use, at the original location, caused some variance in the consumptive use of water. It is the purpose of this study to determine the extent and time of municipal demand and the total effect of the urban use on the supply source and receiving stream. The City of Laramie, Wyoming is the locale and a water budget approach has been used to define the effects.

SECTION IV

BACKGROUND

Location

The location of the project is the City of Laramie and environs in Albany County, Wyoming at an elevation of 7,100 feet above mean sea level. The area lies along the Laramie River which flows in a northerly direction on the floor of the Laramie Basin near the Western front of the Laramie Mountains. The area occupies portions of Townships 15 and 16 North, Range 73 West of the 6th Principal Meridian (Figure 1).

The city area is located on land that has a natural surface drainage westward, directly into the Laramie River. Spring Creek, a small tributary of the Laramie River, skirts the southern edge of the city. The channel of the creek was modified in 1929 to provide a degree of flood protection for the city (Bell, 1967). Most of the storm drains in the southern portion of the city discharge into Spring Creek while the northern section has storm drains that discharge directly to the river.

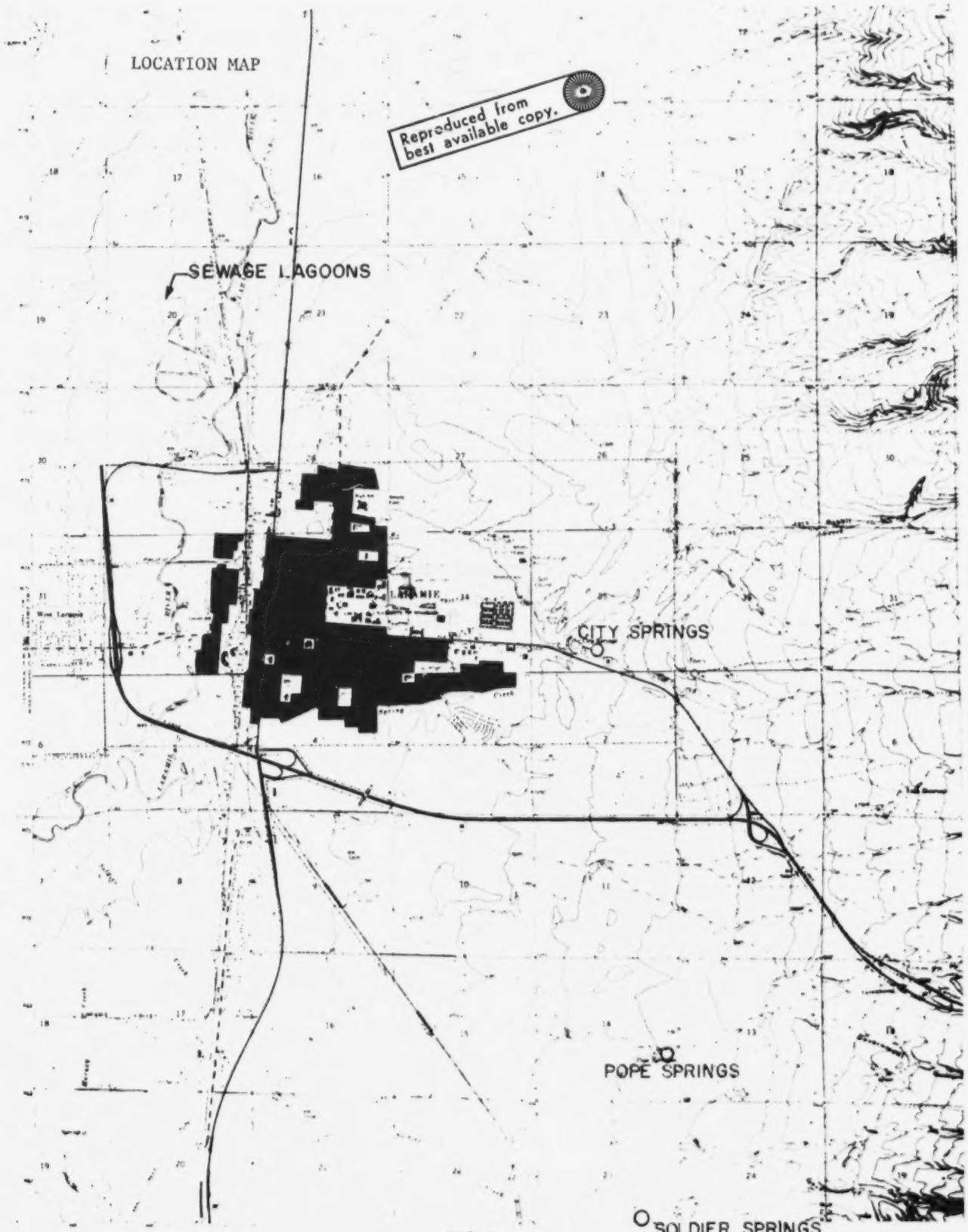
Laramie is primarily a university town with little heavy industry. The influx of students in the fall, with the consequent egress and ingress during the Christmas vacation, and the sudden outpouring from town at the end of school in June, is a constant cyclical pattern. There is no other large single water user which overshadows the effects of the University on the water withdrawals and use.

History

The original water supply to Laramie was from springs which were capable of furnishing enough water for the railroad and the city during its early life. As urban development continued, the springs were not adequate to supply the water necessary for municipal and industrial growth, and the city looked elsewhere for additional water. The most logical source for supplemental supply was the adjacent Laramie River. By the time of need, however, the entire flow of the river had been appropriated, primarily for agricultural use, and a guaranteed supply was not available from the remaining natural flow of the river. The city was able to purchase the earliest water right on the Laramie River and the Wyoming State Board of Control permitted the transfer of that right to municipal use with a consequent change in the point of diversion and place of use.

Geology

The Laramie Basin is a broad syncline trending north and south, bordered on the east side by the Laramie Mountains and on the west by the Medicine Bow Mountains. The strata lying on the west slope of the Laramie Mountains (the east side of the Basin) dip westward at moderate angles of about 4^0 to 6^0.


LOCATION MAP
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SEWAGE LAGOONS
CITY SPRINGS
POPE SPRINGS
SOLDIER SPRINGS

FIG. 1

The Casper Formation, the greatest water-producing aquifer within the Laramie area, is composed of interbedded limestones, sandstones, siltstones and shales. This formation is exposed to meteoric recharge on the dip slopes of the Laramie Mountains east of the City of Laramie and supplies water to the city's springs and wells. Within the municipal area, the Satanka, Forelle, Chugwater, Sundance, and Morrison Formations lie above the Casper Formation and these in turn are covered by a moderate depth of alluvium (9-15 feet). Free groundwater occurs in the alluvium.

Period of Study

The initial installations of some of the gages and instrumentation were made in the spring of 1965 with additional equipment being installed during the summer and fall of 1966. This report is based on the records that have been obtained from May 1965 through December 1970.

SECTION V

PROCEDURES

While the ideal procedure for a study to define a modification in regimen would have been a "before and after" investigation, the actual change in type of water utilization from irrigation to municipal use was accomplished at Laramie in 1947, and no "before" studies existed. Since the same river (Laramie River) passes through and serves as a source of supply for the city and receives its storm and sanitary wastes, it appeared possible by water budget methods to arrive at comparative amounts and patterns of use and return flow.

To define the municipal effects on the streamflow regimen, it was necessary to establish a detailed water budget for the city. This entailed the measurement and recording of all inflow to the city water supply system and the outflow from the city's sanitary system (in the case of Laramie, the sanitary and storm sewers are separate).

The original source of water supply for the City of Laramie was City Springs. Estimates and miscellaneous measurements of the flow from this source were made at various times throughout the developmental period of the city. A concrete Parshall measuring flume was installed in 1940 (Nelson, 1940) but continuous records were not kept until May 1965 when a water level recorder was installed. At the same time (1965) a meter was installed in the line conveying water from Soldier Springs and Pope Wells at the south edge of the city (Rechard and Lane, 1968).

Water from the Laramie River is supplied to the city by diversion from the river, about twenty-one miles southwest of Laramie, to Sodergreen Reservoir, which serves as a primary settling basin and provides limited operating storage. Releases from the reservoir flow by gravity through a 36-inch pipe line into a filter plant from which the water flows in a 20-inch pipe line to Laramie where the treated river water is commingled in the high level reservoirs near City Springs with that from the spring sources.

The City of Laramie, as a contributing portion of the study, constructed or installed metering devices and telemetering equipment to continuously monitor the flow to the city's reservoirs, spill or waste from the reservoirs, and releases to the system for municipal consumption. Thus water supplied to the City of Laramie is now measured and recorded by the City Water Department and their cooperation in making these records available for this study is gratefully acknowledged.

For this study, the most important quantity of water entering the river as it passes through the city is that from the domestic sewerage system. Since the city uses a lagoon type treatment of sanitary sewage, two 24-inch Parshall flumes with Stevens type-F recorders were installed on the ditches leading to the river to record the quantity of lagoon effluent.

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To estimate the evaporation from the lagoon water surface, an evaporation station was installed to National Weather Service (NOAA) standards adjacent to the ponds. The observations collected are published in the Climatological Data for Wyoming. In addition to the Class "A" pan, auxiliary equipment includes a non-recording precipitation gage, a Hellmann type recording precipitation gage (for summer operation), a hygrothermograph, maximum-minimum thermometers for both air temperature and pan-water temperature, and a thermometer for once daily pond water temperature observation. An additional Class "A" pan was filled with water from the lagoons. For the protection of the Class "A" pans, no attempt was made to operate them when freezing temperatures prevailed. Some evaporation undoubtedly occurs from the ice surface on the lagoons and in an effort to obtain an estimate of that amount, a modified weighing Belfort precipitation recorder was installed. The receiving cone was removed and a plastic bucket utilized to prevent damage from the ice. The bucket was filled with water to within two inches of the brim and permitted to freeze. As evaporation occurred, the chart recorded what would appear to be negative precipitation. Because the graduations on the chart were representative of an eight-inch opening and the ice surface was approximately ten inches, it was necessary to correct the apparent evaporation by a factor of 0.64 to obtain meaningful readings. It is believed that the gage has considerable potential for winter evaporation measurement. Also, coffee cans were filled with water and permitted to freeze, the evaporation-sublimation from them was determined by daily weighing the cans and ice.

Data

Table I shows the inflow to the Laramie municipal water system as recorded by the city. The contributions from each of the three sources of supply are set forth. As noted previously, the flow from Soldier Springs and Pope Wells is commingled and brought to Laramie in one pipe. The recorder is in the pipeline as it enters the city and, therefore, the flow from these two sources are reported as a combined figure.

The records of spill and change in storage in the city's reservoirs were not maintained prior to March 1967, when the instruments installed by the city first became operational. Because the quantities were small and because management methods were different after the installation of the telemetry system, no attempt was made to estimate these items for the previous period.

Table II is the annual summary of the monthly data presented in Table I. These data show that on the average for the 1966-1970 period, the Laramie River, the City Springs, and Pope and Soldier Springs each furnished about one-third of the annual requirement of the City of Laramie.

Table III summarizes the data of Tables I and II by months. Because the flow of the City Springs is not artificially controlled, the contribution from this source is practically constant. Pope and Soldier Springs have been developed, and the flow from these sources can be increased by pumping. In the early years of the city, these sources, with the aid of

TABLE I

MONTHLY WATER SUPPLY FOR THE CITY OF LARAMIE, WYOMING
(Acre-Feet except as noted)
May 1965 - December 1970

Month/Year	City Springs	Pope & Soldier Springs	Laramie River	Spillage & Δ Storage	Total to Consumers	% Total from River	% of Annual
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
May 1965	143	145	63		351	18	
June	138	207	96		441	22	
July	143	248	286		677	42	
Aug	140	205	245		590	42	
Sept	130	178	86		394	22	
Oct	136	122	53		311	17	
Nov	131	169	50		350	14	
Dec	131	159	35		325	11	
Jan 1966	138	126	86		350	25	8.0
Feb	140	142	66		348	19	8.0
Mar	140	153	74		367	20	8.4
Apr	138	163	48		349	14	8.0
May	138	187	188		513	37	11.8
June	132	170	121		423	29	9.7
July	137	163	152		452	33	10.4
Aug	133	186	99		418	24	9.6
Sept	130	195	56		381	15	8.8
Oct	81	145	16		242	7	5.6
Nov	110	125	17		252	7	5.8
Dec	121	131	4		256	2	5.9
Jan 1967	120	120	42		282	15	6.4
Feb	120	120	30		270	11	6.2
Mar	128	113	46	11	276	17	6.3
Apr	124	131	77	22	310	25	7.1
May	122	152	138	18	394	35	9.0
June	121	99	150	3	367	41	8.4
July	127	136	313	0	576	54	13.2
Aug	128	120	391	3	636	61	14.5
Sept	120	147	155	0	422	37	9.7
Oct	129	118	106	-3	356	30	8.1
Nov	122	90	37	1	248	15	5.7
Dec	127	94	11	-1	233	5	5.3
Jan 1968	126	103	48	2	275	17	6.3
Feb	118	84	33	-1	236	14	5.4
Mar	127	102	36	2	263	14	6.1
Apr	126	96	41	3	260	16	6.0
May	129	110	85	3	321	26	7.4
June	134	145	369	3	645	57	14.9
July	137	141	313	7	584	53	13.5
Aug	138	166	161	-3	468	35	10.8
Sept	132	193	159	4	480	33	11.1

TABLE I (Continued)

Month/Year	City Springs	Pope & Soldier Springs	Laramie River	Spillage & Δ Storage	Total to Consumers	% Total from River	% of Annual
Oct 1968	130	142	41	-12	325	13	7.5
Nov	133	105	2	8	232	1	5.4
Dec	138	112	10	14	245	4	4.9
Jan 1969	138	117	16	10	261	6	5.1
Feb	125	108	14	4	244	6	4.8
Mar	140	129	15	2	283	5	5.6
Apr	138	141	105	3	381	27	7.6
May	140	137	309	7	580	53	11.5
June	136	139	176	4	447	39	8.9
July	139	126	513	0	778	66	15.4
Aug	138	117	452	2	706	64	14.0
Sept	127	159	226	-5	517	44	10.3
Oct	139	141	24	-5	309	8	6.1
Nov	135	118	15	3	265	6	5.3
Dec	138	116	17	0	271	6	5.4
Jan 1970	137	122	17	-3	279	6	5.4
Feb	128	119	15	0	261	6	5.1
Mar	127	121	20	0	269	7	5.3
Apr	146	132	46	10	314	14	6.1
May	137	182	219	3	535	41	10.4
June	136	192	329	4	653	50	12.7
July	137	148	456	3	738	62	14.4
Aug	138	182	414	8	712	56	14.1
Sept	133	214	68	4	411	16	8.0
Oct	139	169	43	0	351	12	6.8
Nov	134	125	34	0	293	12	5.7
Dec	140	129	36	0	305	12	6.0

TABLE II

ANNUAL WATER SUPPLY FOR THE CITY OF LARAMIE, WYOMING
(Acre-Feet except as noted)
1966-1970

Calendar Year	City Springs (1)	Pope & Soldier Springs (2)	Laramie River (3)	Spillage & Δ Storage (4)	Total to Consumers (5)	% Total from River (6)
1966	1,538	1,886	927	0	4,351	21.3
1967	1,487	1,440	1,496	52	4,371	34.2
1968	1,568	1,499	1,298	31	4,334	29.9
1969	1,633	1,548	1,882	21	5,042	37.3
1970	1,632	1,835	1,697	30	5,134	33.1
Average	1,571	1,644	1,460	29	4,646	31.4

TABLE III

SUMMARY
MONTHLY AND ANNUAL WATER SUPPLY FOR THE CITY OF LARAMIE, WYOMING
(Acre-Feet except as Noted)
1966-1970

Source	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual	% Total to Consumer
	66	138	140	140	138	138	132	137	133	130	81	110	121	1,538	
City	1967	120	120E	128	124	122	121	127	127	120	129	122	127	1,487	
Springs	68	126	118	127	126	129	134	137	138	132	130	133	138	1,568	
	69	138	125	140	138	140	136	139	138	127	139	135	138	1,633	
	70	137	128	127	146	137	136	137	138	133	139	134	140	1,632	
	Avg.	132	126	132	134	133	132	135	135	128	124	127	133	1,571	33.8
% Avg.Annual		8.4	8.0	8.4	8.5	8.5	8.4	8.6	8.6	8.1	7.9	8.1	8.5	100	
	66	126	142	153	163	187	170	163	186	195	145	125	131	1,886	
Pope &	1967	120	120E	113	131	152	99	136	120	147	118	90	94	1,440	
Soldier	68	103	84	102	96	110	145	141	166	193	142	105	112	1,499	
Springs	69	117	108	129	141	137	139	126	117	159	141	118	116	1,548	
	70	122	119	121	132	182	192	148	182	214	169	125	129	1,835	
	Avg.	118	115	124	133	154	149	143	154	182	143	113	116	1,644	35.4
% Avg.Annual		7.1	7.0	7.5	8.1	9.3	9.1	8.7	9.4	11.1	8.7	6.9	7.1	100	
	66	86	66	74	48	188	121	152	99	56	16	17	4	927	
Laramie	1967	42	30E	46	77	138	150	313	391	155	106	37	11	1,496	
River	68	48	33	36	41	85	369	313	161	159	41	2	10	1,298	
	69	16	14	15	105	309	176	513	452	226	24	15	17	1,882	
	70	17	15	20	46	219	329	456	414	68	43	34	36	1,697	
	Avg.	42	32	38	63	188	229	349	303	133	46	21	16	1,460	31.4
% Avg.Annual		2.9	2.2	2.6	4.3	12.9	15.7	23.9	20.8	9.1	3.1	1.4	1.1	100	
	66	350	348	367	349	513	423	452	418	381	242	252	256	4,351	
Total	1967	282	270	276	311	394	365	575	636	425	356	248	233	4,371	
to	68	275	236	263	260	321	645	584	468	480	325	232	245	4,334	
Consumer	69	261	244	283	381	580	447	778	706	517	309	265	271	5,042	
	70	279	261	269	314	535	653	738	725	411	351	293	305	5,134	
	Avg.	289	272	292	323	469	507	625	591	443	317	258	262	4,646	100.0
% Avg.Annual		6.2	5.9	6.3	7.0	10.1	10.9	13.5	12.7	9.5	6.8	5.5	5.6	100	

watering restrictions (Mason, 1939:271-282), were able to satisfy the municipal demands. Pope and Soldier Springs provide some flexibility in the supply, especially by being able to pick up the September demand when the flow of the Laramie River is low.

The Laramie River supplements the ground water sources by supplying the larger demands imposed by lawn irrigation. The only major regulation of natural flow on the Laramie River above the intake to the city's system is Sodergreen Reservoir, and this reservoir is not sufficient to provide for more than monthly pondage. Should the winter demands for domestic use increase considerably, the city may be forced to look for more storage on the river.

Table IV shows the monthly distribution of water supplied to the city. As is expected the larger demands are during the summer when lawn irrigation is underway. There is some shifting of the peak demands among the summer months. A comparison of these shifts with the precipitation records indicates that the explanation for these changes is the absence or presence of summer precipitation.

The discharge from the sewage lagoons constitutes the measurable return flow from the city to the Laramie River. The outflow from the lagoons is summarized in Table V.

Prior to October, 1966 discharges were estimated by assuming the weirs used as the outlet from the lagoons would operate in accordance with a standard weir formula. Following the installation of the Parshall flumes in September, 1966, the return flow shown in the table was the recorded value. The accuracy of the flume rating tables was confirmed by several measurements made utilizing the dye-dilution procedure.

Missing (due to ice conditions) records of discharge from the lagoons were estimated using periodic (usually once weekly) readings of the staff gages on the ponds or at the flumes and from observation that the flow fluctuates little during these months. When records for only portions of the month were obtained, the average daily flow during the partial month was assumed to be representative of the average for the entire month. During the winter 1969-1970 considerable difficulties were encountered in maintaining the flumes and the canals. The records for these months were so poor that they are not included.

The percentage of the water supplied the city that is returned to the river during the same month is shown in Table VI. The impact of lawn irrigation is again evident. During the winter months (October-March) the return flow is 84 percent of the inflow, while for the summer months (April-September) only 54 percent of the inflow is returned.

During the 1966-1970 period the river usually supplied about one-half of the inflow during the summer months, so with the help of ground water, the Laramie River was not seriously depleted by the city. In fact, on an annual basis, the city returns to the river more water than it diverts.

TABLE IV

MONTHLY DISTRIBUTION OF TOTAL WATER SUPPLIED TO CONSUMERS

(Percent)

MO \ CY	1966	1967	1968	1969	1970	Mean
Jan	8	7	6	5	5	6
Feb	8	6	5	5	5	6
Mar	8	6	6	6	5	6
Apr	8	7	6	8	6	7
May	12	9	7	12	10	10
June	10	8	15	9	13	11
July	10	13	14	15	15	13
Aug	10	15	11	14	14	13
Sept	9	10	11	10	8	9
Oct	6	8	8	6	7	7
Nov	5	6	5	5	6	6
Dec	6	5	6	5	6	6
Annual	100	100	100	100	100	100

TABLE V

MONTHLY RETURN FLOW FROM THE CITY OF LARAMIE, WYOMING
(SEWAGE LAGOON OUTFLOW)
(Acre-Feet)

YEAR	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
1966	280	244	250	191	191	226	190	228	215	227	176	246	2,664
67	223	196	189	215	224	273	256	225	211	232	214	228	2,686
68	230	211	228	243	284	282	262	287	229	243	239	235	2,973
69	230	225	266	247	247	293	257	244	212				2,221**
1970				277	251	382	334	307	253	387*	240		2,044**
Avg.	241	219	233	235	239	291	260	258	224	234**	217	236	2,887

* Artificially inflated by draining lagoon
** Total of validly recorded figures only

TABLE VI

PERCENTAGE RETURN FLOW (SEWAGE LAGOON OUTFLOW) IS OF INFLOW TO CONSUMERS
LARAMIE, WYOMING

YEAR	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1966	80	70	68	55	37	53	42	55	56	94	70	96
67	79	73	68	69	57	74	45	36	50	65	86	98
68	84	89	87	93	88	44	45	61	48	75	100	96
69	88	92	94	65	43	66	33	35	41			
1970				88	47	58	45	42	62		82	
Avg.	83	81	79	74	54	59	42	46	51	78	84	97

Note: Avg. Winter 6 months = 84%
Avg. Summer 6 months = 54%

Table VII shows patterns of weekly sewage flow from the city as recorded in the sewer line prior to discharge into the sewage lagoons. The weeks chosen to represent typical situations included both those when the University was in session and when there was vacation. The influence of the University on the amount of sewage flow is obvious. The start of the long vacation recesses are quite evident and while the University is in recess, the sewage flows drop to approximately 80 percent of their normal. Usually the weekly peak sewage flow occurs on Monday; however, the variations within a week are not great and the weekend flow varies little from the midweek flow patterns. The flow does have a marked diurnal fluctuation with the maximum rate of about 3.5 mgd, occurring during the noon or early afternoon hours, and the minimum flow, approximately 1.8 mgd, occurring between six and eight A.M.

Climate affects the municipal demand as well as the amount of evaporation that occurs from the surface of the lagoons. The pertinent climatic factors, precipitation, evaporation and mean temperature, are given in Table VIII. As mentioned earlier, the summer precipitation inversely influences the demand for lawn irrigation water. Likewise, the monthly temperature directly affects the demand. This latter fact is shown in Figure 2, which is a plotting of mean monthly temperature against the municipal inflow.

TABLE VII

TYPICAL MEAN DAILY
MUNICIPAL SEWAGE FLOWS

(Millions of Gallons)

	Nov. 12-18, 1967	Nov. 19-25, 1967*
Sun.	2.49	2.59
Mon.	2.76	2.82
Tues.	2.74	2.72
Wed.	2.72	2.54[1]
Thurs.	2.69	2.27
Fri.	2.72	2.35
Sat.	2.78	2.31

	Dec. 10-16, 1967	Dec. 17-23, 1967**
Sun.	2.81	2.12
Mon.	2.75	2.22
Tues.	2.75	2.11
Wed.	2.66	2.08
Thurs.	2.53	2.01
Fri.	2.49	2.16
Sat.	2.23[1]	2.16

* During University of Wyoming Thanksgiving Recess

** During University of Wyoming Christmas Recess

[1] First Day of Recess

TABLE VIII

PRECIPITATION AND EVAPORATION AND TEMPERATURE AT LAGOONS

Precipitation (Inches)

YEAR	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
1966	.14	.17	.64	.29	.16	1.19	1.79	.79	2.10	.40	.33	.09	8.09
67	.94	.18	.37	1.07	1.15	2.79	1.70	1.08	1.19	.63	.03	.30	11.43
68	.06	.44	.10	2.63	1.68	.33	1.66	1.05	.37	.49	.59	.12	9.52
69	.23	.86	.06	.62	.57	3.11	.87	.49	1.10	1.57	.22	.19	9.89
1970	.03	.11	.60	.23	.91	2.07	1.83	.59	1.54	1.57	.85	.12	10.45

Evaporation (Inches)

YEAR	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
1966					10.97	11.88	12.10	10.81	7.62				53.38
67					8.89	8.22	9.76	9.21	7.52	6.62*			50.22
68					8.66	12.25	10.28	10.37	7.41				48.97
69					10.04	8.12	12.73	10.37	8.24				49.50
1970					10.34	10.19	11.50	10.27	7.03				49.33

* Not included in annual total

Mean Temperature (^{0}F)

YEAR	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	MEAN
1966	21	20	32	36	48	56	66	59	53	47	38	23	42
67	23	22	33	39	44	53	62	58	51	44	32	14	40
68	25	25	34	34	45	56	63	57	47	43	26	21	40
69	26	21	19	42	51	52	64	64	56	32	28	24	40
1970	22	28	24	33	48	55	63	64	50	34	30	24	40

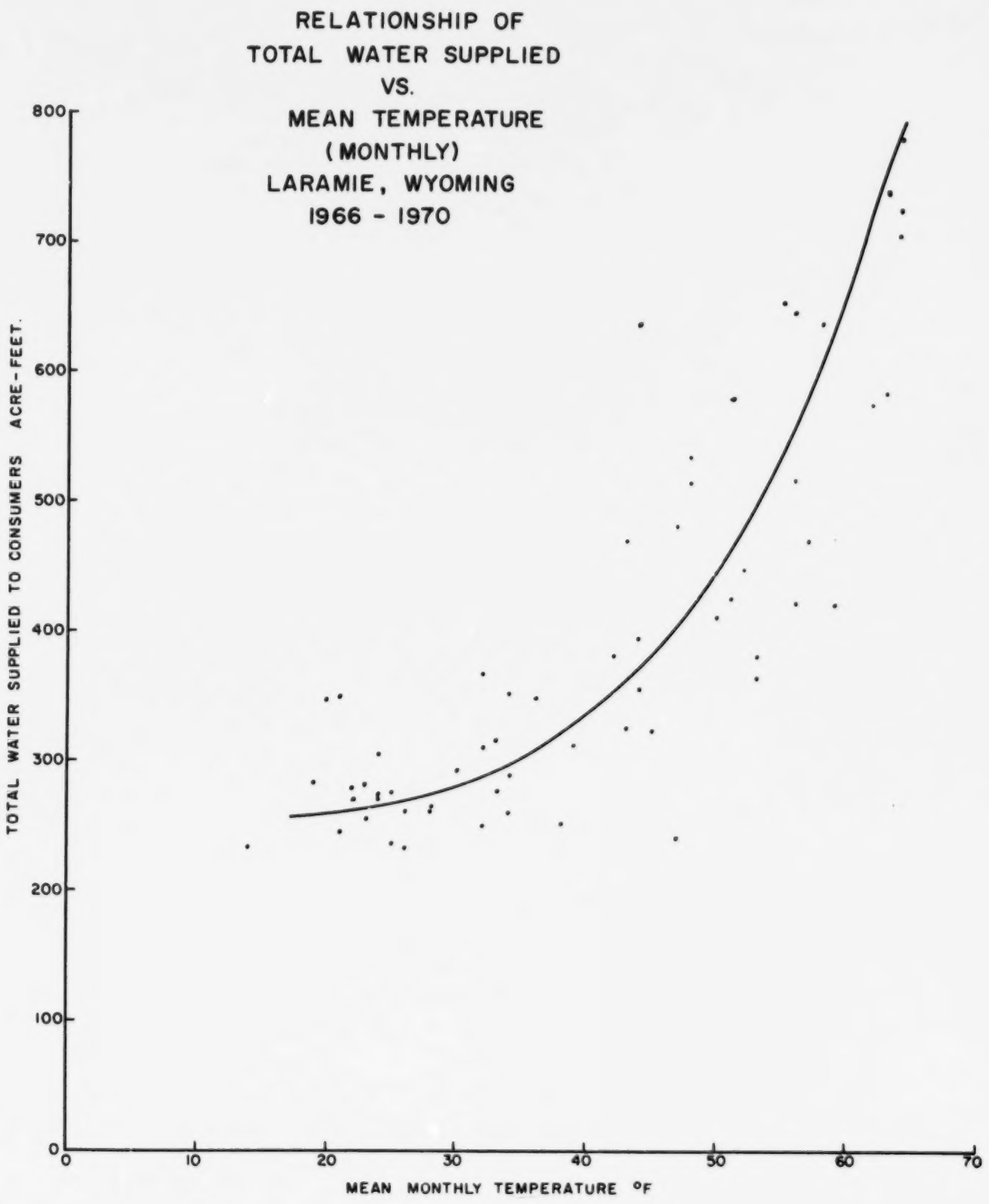
RELATIONSHIP OF
TOTAL WATER SUPPLIED
VS.
MEAN TEMPERATURE
(MONTHLY)
LARAMIE, WYOMING
1966 - 1970
TOTAL WATER SUPPLIED TO CONSUMERS ACRE-FEET.
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
MEAN MONTHLY TEMPERATURE °F

FIG. 2

SECTION VI

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*U. S. GOVERNMENT PRINTING OFFICE : 1972--484-483/60

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SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No. | 2. | 3. Accession No. W

4. Title

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5. Report Date

6.

8. Performing Organization Report No.

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Rechard, P. A.

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12. Sponsoring Organization

15. Supplementary Notes

16. Abstract

The water budget for the City of Laramie, Wyoming was observed for a five-year period (1966-1970). The purposes were to supplement studies of the operation of the city's sewage lagoons and to define the effects of municipal use on the Laramie River which furnished part of the water supply and was the receiving stream for the sewage effluent.

It was found that the river furnished approximately one-third of the annual supply and more than one-half the supply during the summer irrigating season. The city returned to the river about fifty percent of the water received during the summer (April-September) and eighty-five percent during the winter (October-March).

The municipal supply averaged 184 gallons per capita per day during the period of the study and varied from 134 gpcd during the winter to 235 gpcd during the summer. The average return flow to the river was 115 gpcd with 140 gpcd returning in the winter and 105 gpcd in the summer period.

17a. Descriptors

Water budget, municipal use, urban water supply, weather data, water utilization

17b. Identifiers

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